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Research Article

A Shannon Entropy Approach for Quantitative Evaluation of Resilience and Sustainability for Transport Infrastructures

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Abstract

This paper presents an original methodology for quantitative evaluation of resilience and sustainability in transport infrastructure projects, specifically focusing on highways and earthworks construction. The methodology employs Shannon entropy theory to assess five key resilience criteria: technical, socio-economic, environmental, climate change adaptation, and strategic aspects. A probabilistic approach is used to calculate resilience indices, enabling comparative analysis between traditional and innovative construction technologies. According to this approach, in resilience studies conducted for a new project it is recommended to investigate at least two alternatives, a classical/standard one in parallel with the new proposed one. The resilience value obtained for each investigated project is compared with the resilience of an ideal project, so that to be possible decide which alternative is more near the ideal solution and thus may better satisfy, the designed / desired resilience requirements This proposed methodology is validated through a case study of the Tarhuna-Beni Walid road project in Libya, where dry compaction technology was implemented to address water scarcity challenges. Results demonstrate that the proposed approach achieved a resilience index of 2.16 bits compared to 3.98 bits for conventional methods, indicating superior resilience performance. The methodology provides practitioners with a quantitative framework for infrastructure decision-making and risk assessment.

Keywords

Transport Infrastructures, Shannon Entropy, Project Resilience & Sustainability, Road Earthworks

1. Introduction

The execution of earthworks is primarily subject to geotechnical and climatic hazards, when many parameters and constraints, such as variety and heterogeneity of materials (soils) encountered in the site, extraction and implementation difficulties: loose soils, rocky soils, climatic conditions, water supply for compaction, drainage and surface water controls, interfaces with other activities (pavements, bridges, etc.…), influence the normal flow of operations. In accordance with these specific considerations, this research study on evaluation of project sustainability and resilience, takes into account the technical, social –economic, environmental and strategic aspects as well as concepts on adaptation to climate change for earthworks processes and for the construction of earth-structures.

In this context, this paper presents the results of developing an original methodology for the quantitative evaluation of the resilience and sustainability of transport infrastructures, based on a probabilistic approach and on Shannon entropy. Finally, a practical guide including a concrete example of resilience evaluation and monitoring, at project level, for the earthworks

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construction of the road Tarhuna – Beny Walid, located in the Libyan desert.

2. The Actual State of Art

According the existing research and literature [1], at this stage, " *no specific resilience indicators on infrastructure assets have been found"* and *"a common methodology applied broadly by the academic and/or technical community for evaluation of resilience of earthworks or /end of earth structure at the project level does not currently exist"*.

However, some methodologies applied experimentally, at *the infrastructure assets level* (such as to earth structures) on road or other transport systems have been developed for specific case studies, by using risk management approach or risk exposure also on the infrastructure project level.

3. Method for Quantitative and Qualitative Resilience Evaluation

The aim of this study is to develop and to propose a general methodology for quantitative and qualitative resilience evaluation, at project level, of highway earthworks and earth structure, and to try to apply this methodology on some specific groups of case studies, recently just described and published in the frame of both PIARC TC3.4 technical comities: WG-1 and WG-2.

In order to establish a general method for quantitative and qualitative resilience evaluation, at project level, of highway earthworks and earth structure, we may assume that in any road project related to earthworks processes or to the construction of earth structures, there must achieve a balance between the main pillars of resilience: technical, social – economic, environmental and strategic aspects, as well as concepts on adaptation to climate change. Consequently, in any analysis of project resilience, at least the following five resilience criteria has to be considered and selected:

1) Technical criteria: (T)
2) Social –economic criteria: (Ec)
3) Environ -mental criteria (Env)
4) Adaptation to climate change (Acc) alone or in combination with Environmental criteria (Env & Acc)
5) Safety &Strategic Development (SSD).

The identification and measurement of each of these five aspects, must be performed in each stage of the life of earthworks or of earthworks structures, starting with the design and choice of materials and continuing with the execution, maintenance and rehabilitation.

For each case study earthwork project, it is necessary to identify the main factors that are involved, to collect data necessary for their evaluation and to apply the mathematical and statistical tools, useful for estimating, the impacts which they may produce separately, then to and to evaluate qualitatively and when possible quantitatively, their cumulative impacts. Therefore, a thorough analysis is needed to assess the resilience of such projects. Such a detailed analysis, based on experience, literature and specific aspects of the project, must be undertaken for each of the subsystems of the investigated resilience system.

Before proceeding for assessing/ evaluation of the resilience of earthworks or of an earth- structure, the aims and priorities of the project must be taken into account accordingly, and the following aspects must be clarified:

1) Adopt and described *the strategies necessary* to achieve the requirements of these components. According to these approaches, in resilience studies conducted for a new project it is recommended to investigate *at least two alternatives, a classical/standard one in parallel with the proposed one, so that, finally to be possible to compare and decide which alternative may better satisfy, the designed / desired resilience requirements.*
2) *Thus*, in case of a new solution/ project, for justifying its implementation, in comparison with the classical/standard ones, it *will be necessary to include in the evaluation study, at least one classical project, considered as a reference one*.
3) In this respect, for each alternative project, consider the five components of resilience: T, SE, E, SSA, SCC, AC-E, as being independent systems, of them being structured by a finite number of subsystems.
4) For each subsystem, according its specific aspect/ quality, on may assign a corresponding quantitative or qualitative weighing factor, *expressed in term of the probability with which that specific quality, will possible to be achieved/assured by the investigated technology.*
5) Describe in detail the problem encountered, the context in which it appeared and the new innovative solution/ project intending to resolve the existing problem, in comparison with the classical ones.
6) Function of the specific / complexity of the project, select *and describe in detail, the specific resilience systems and subsystems, which should be investigated and evaluated in terms of probabilities established for the evaluation of resilience in the both, the reference project and the new proposed one.*
7) For each, aspect/subsystem (i = 1…n) selected for resilience investigation, choose *the appropriate qualitative and/or a quantitative methods for evaluation of the subsystem achievement probabilities.* Such a detailed analysis, based on experience, literature and specific aspects of this project, must be undertaken for each of the subsystems of the both investigated resilience systems, X1 and X2, as shown in Chapter 4.
8) *For each investigated project, based on these subsystems probability values, calculate for each alternative project, the resulting Resilient Index of the system (i)*, $I_{Ri,}$ expressed in terms of bits, according existing literature [2, 3], Classical Entropy formula (1)

$$H(X_i) = \sum_1^n P(xi) \log b\, P(xi) \quad (1)$$

Where, the variables have the following significance:

H (X) is the entropy value, expressed in digits of bits, of the complex H system, composed from (n) subsystems, when i = 1, 2, 3, n.

(xi) Is the indicative of the subsystem (i);

$P_{(xi)}$ is the estimated probability, with which the technical or other requirements of the subsystem (i), may achieve the designed/ desired quality, expressed in quantitative or qualificative values; The sum of the P(xi) = 1

(b) is the base of the logarithm, (b=2, for Shannon entropy calculation);

9) Lets consider the following two earthworks projects systems: X1- the new proposed project and X2- the reference, classical project. The new proposed project X1 is composed of the subsystems: $x_{11}, x_{12}, \dots x_{1n}$), each subsystem being characterized by its corresponding probability: $P(x_{11})$, $P(x_{12})$, … $P(x_{1n})$. Similarly, the reference project X2 is composed of the subsystems: $x_{21}, x_{22}, \dots x_{n}$), each subsystem being characterized by its corresponding probability: $P(x_{21})$, $P(x_{22})$, … $P(x_{2n})$.
10) Evaluate/calculate the Resilient Index (Re_{new}), according the Shannon formula for the evaluation of the entropy of the investigated system, expressed in digit units of information (bits), for the new proposed project with relation (2)

$$RI\ new = H(X1) \quad (2)$$

11) Evaluate/calculate the Resilient Index ($RI_{\_ref}$), according the Shannon formula for the evaluation of the entropy of the investigated system, expressed in digit units of information (bits), for the reference project, with the relation (3):

$$RIref = H(X2) \quad (3)$$

12) Finally, compare between the values of both Resilience Indexes: RI_{-new}, and the respected RI_{ref}, and also with the resilience value RI_{ideal} corresponding to the ideal project X3, calculated according the relations (4) & (5), and finally, decide which project will be selected and undertaken for construction, based on its feasibility and resilience efficiency.

$$RIideal = H(X3) \quad (4)$$

Note: The value of Shannon Entropy RI_{ideal} for the ideal resilience system H(X3) is zero, as shown in the second part of this study, addressing a concrete application case study.

For example, in that investigated case, it was assumed assuming, that for a similar ideal earthwork project, each aspect of the five resilience aspects involved, is achieved with a specific /desired probability, as follows: $p(x_{31}) = 1{,}00$; $p(x_{32}) = 1{,}00$; $p(x_{33}) = 1{,}00$; $p(x_{34}) = 1{,}00$; $p(x_{35}) = 1{,}00$
so that the value of the of Shannon Entropy $RI_{ideal,}$ will be:

$$RIideal = 0{,}00 \quad (5)$$

13) Formulate the final conclusions and appreciation about the resilience of the new project, and justify the need for its implementation and specify its main aspects, which has to be observed and supervised, during stages of earthworks construction and also those of performance monitoring, after the delivery of the road for traffic.

4. Example of Application: This Methodology to a Specific Road Earthwork Project

4.1. Project Description: Brief Summary of the Compaction Technology Problem

The Tarhuna – Beni Walid Road is a two-lane asphalt concrete highway that connects the cities of Tarhuna and Beni Walid in northern Libya. Built during 1975 – 1980, the roadway crosses more than 97 km through an extremely arid desert environment and it is the only transportation route between the two cities. Water in the area is scarce and finding and hauling large amounts of water for soil compaction operations during the construction of the project was a major challenge.

4.1.1. Brief Summary of the Solution

The great majority of the subgrade soils along the construction route were granular (coarse-grained) with natural moisture contents between 1% and 3%. A great number of Modified Proctor [4], laboratory compaction curves involving ten different soil samples and more than five hundred standard compaction tests, were developed for both coarse-grained and fine grained soils encountered along the road route. Thus, for the AASHTO course-grains soils A-1, A-2 and A-3, an unusual local maximum was

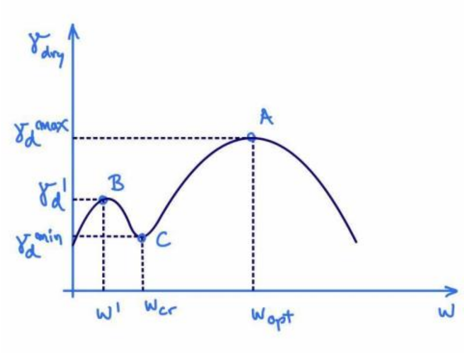

Figure 1. *Schematic of Modified Proctor compaction curve for granular soil showing local maximum at low moisture (Point B) and the traditional maximum dry density at optimum moisture content (Point A). Also this curve shows a minimum dry density corresponds to a critical moisture content wcr (Point C).*

For the fine-grained soils such as AASHTO A-4, A-5, A-6, the Proctor curves were presented similar irregular shapes, with the particularity that the local maximum at low moisture content (point B) was located on the ordinate, corresponding to a complete dry condition (moisture content $w^1 = 0$). To reduce the amount of water required for compaction, the solution was to take advantage of the observed local maximum in dry unit weight (point B on the compaction curve) and to compact the soils at the site at the corresponding lower moisture content w^1. Although γd^1 is lower than γdmax, the required relative compaction of 95% of γdmax was generally achieved without any difficulties in the field, using only vibratory rollers. The dry density curve also shows a minimum at point C, corresponding to a critical moisture content wcr. Compaction at this moisture content should be avoided.

4.1.2. Lessons Learned

1) As at this stage, the phenomena occurring during soil compaction are not fully understood, taking into consideration the limited research facilities of a site laboratory, and considering mainly the Proctor's capillarity and lubrication theory, the aim of our research was focused to find out, by examining from a macroscopic level, what are the main geotechnical characteristics of soil, such its grading, the moisture content, the liquid limit, plasticity index, which may affect the shape of its moisture –density compaction curve.
2) The extensive laboratory investigation involving ten different soil samples and more than five hundred standard compaction tests revealed many irregularly shaped compaction curves. The majority of coarse – grained soils, having a liquid limit less than 25, clearly reveal the existence of double peaks, as shown in Figure 1. A number of different irregular shapes was found to be characteristic for some sandy, silts and clayey soil specimens. The soil samples tested, with a liquid limit higher than 25, usually yield typical 1&1/2 or single peaks compaction curves.
3) Based on the laboratory and field research, involving complete Proctor curves, as shown in Figure 1, it was found that most of coarse-grained soils, (AASTHO classification A-1, A-2, and some of A-3) are suitable for dry compaction.
4) The investigated fine-grained soils (AASHTO classification A-4, A-5, A-6), were found to be unsuitable for application of dry compaction. However, for these soils, even in non desert areas, it is recommended to perform complete laboratory Proctor tests, in order to find out the value of critical moisture content (wcr), which is a very important parameter for the earthworks engineer, indicating how to avoid the inefficient use of the compaction equipment, on soils having such moisture. (For this reason, this recommendation, valuable for all types of soils, has been included in the Romanian standards for earthworks. (STAS 1913-13 -83 «Foundation soil. Determination of Compaction Characteristics. Proctor test»)

4.2. Case Study: Resilience Evaluation for Construction of the Tarhuna Beni-Walid Road Project, in Libya

4.2.1. General Recommendations: Main Aspects to Be Clarified Before Proceeding with Any Evaluation

In accordance with the proposed methodology, described in Chapter 2, the main objective of this study, in order to evaluate the earthworks resilience of this project, is to consider each of the main pillars of resilience: technical, social –economic, environmental and strategic aspects, as well as concepts on adaptation to climate change.

For each case study earthwork project, it is necessary to identify the main factors that are involved, to collect data necessary for their evaluation and to apply the mathematical and statistical tools, useful for estimating, the impacts which they may produce separately, then to and to evaluate qualitatively and when possible quantitatively, their cumulative impacts. Therefore, a thorough analysis is needed to assess the resilience of such projects.

Before proceeding for assessing/ evaluation of the resilience of earthworks or of an earth- structure, the aims and priorities of the project must be taken into account accordingly, and the following aspects must be clarified:

Adopt and described *the strategies necessary* to achieve the requirements of these components. According to these approaches, in resilience studies conducted for a new project it is recommended to investigate *at least two alternatives, a classical/standard one in parallel with the proposed one, so that, finally to be possible to compare and decide which alternative may better satisfy, the designed / desired resilience requirements.*

Thus, in case of a new solution/ project, for justifying its implementation, in comparison with the classical/standard one, it *will be necessary to include in the evaluation study, at least one classical project, considered as a reference one*:

1) Technical criteria: (T);
2) Social –economic criteria: (Ec);
3) Environmental criteria (Env)
4) Adaptation to climate change (Acc), alone or in combination with Environmental criteria (Env & Acc)
5) Safety &Strategic Development aspects (SSD).

The identification and measurement of each of these five aspects, must be performed in each stage of the life of earthworks or of earthworks structures, starting with the design and choice of materials and continuing with the execution, maintenance and rehabilitation.

For each case study earthwork project, it is necessary to identify the main factors that are involved, to collect data necessary for their evaluation and to apply the mathematical and statistical tools, useful for estimating, the impacts which they may produce separately, then to and to evaluate qualitatively and when possible quantitatively, their cumulative impacts. Therefore, a thorough analysis is needed to assess the resilience of such projects.

4.2.2. Example of Application of the New Methodology

Here follows an example of application for selecting and conducting a detailed analysis, based on experience, literature of the specific aspects of the resilience system involving the use of the new dry compaction technology (Resilience systems, X1) in comparison with the classical wet compaction (Resilience system X2) for the earthwork construction in the road project of Tarhuna Beny-Walid.

In order to evaluate the degree/ the measure in which each of the investigated projects X1 and X2, satisfy the designed/ desired resilience requirements, it is also necessary to consider from the very beginning, the resilience value, RI_{ideal} corresponding to an ideal project (X3).

Finally, we have to compare between the values of both Resilience Indexes: RI_{-new}, and the respected RI_{ref}, and also with the resilience value RI_{ideal} corresponding to the ideal project (X3), calculated according the relations (4) & (5), and finally, decide which project will be selected and undertaken for construction, based on its sustainability and resilience efficiency.

The value of Shannon Entropy RI_{ideal} for the ideal resilience system H(X3) is zero, as shown in the second part of this study, addressing a concrete application case study.

For example, in that investigated case, it was assumed assuming, that for a similar ideal earthwork project, each aspect of the five resilience aspects involved, is achieved with a specific /desired probability, as follows: $p(x_{31})$ =1,00; $p(x_{32})$ = 1,00; $p(x_{33})$ = 1,00; $p(x_{34})$ = 1,00; $p(x_{35})$ = 1,00
so that the value of the of Shannon Entropy $RI_{ideal,}$ will be RI_{ideal} = 0,00.

Note 1*): The calculations of the various values of Shannon entropy from Table 1, has been done, by using *"the online calculator computes Shannon entropy for a given event probability table and for a given message "*/ reference: https://planetcalc.com/2476/#

Calculation of the corresponding Shannon Entropy values, has been performed by using the relation (1), from Chapter 3.

Table 1. *The Envisaged / Desired Objectives Established for Each Resilience Systems and Their Corresponding Subsystems (Evaluate Risk and Resilience. Establish Resilience Goals and Strategies. Maximize Resilience. Improve Infrastructure Integration).*

Crt. No	**The investigated resilience subsystem**	**Specific / envisaged project objectives/ or requirements**	**The probability for achievement of the specific project requirement and / its entropy value (bits)**			**Observation/ comments/ justifications: project specifications or the desired/envisaged probability of achievement**
			Ideal project: [X3]	**Standard / classical project: (X2)**	**new proposed Project: (X1)**	
1	RESILIENCE TECHNICAL SUBSYSTEM (T)					
	T1.1	The achievement, in the site, of minimum 95% compaction degree of soil	1,00 --------- 0,00	0,95 -------- 0,29	0,95 ------- 0,29	By achievement the Project specification
	SSD1	Improve Community Quality of Life	1,00 ------------- 0,00	0,50 ------------ 0,50	0,50 ---------- 0,50	By providing a new modern road infrastructure min 50% from the

Crt. No	The investigated resilience subsystem	Specific / envisaged project objectives/ or requirements	The probability for achievement of the specific project requirement and / its entropy value (bits) Ideal project: [X3]	Standard / classical project: (X2)	new proposed Project: (X1)	Observation/ comments/ justifications: project specifications or the desired/envisaged probability of achievement
						desired/ideal of 100%
	SSD2	Improve Community Mobility	1,00 ------ 0,00	0,50 ------------- 0,50	0,50 ------------- 0,50	By providing a new modern road infrastructure min 50% from the desired/ideal 100%
	Total entropy Technical:(bits)		0,00	1,29	1,29	
	JUSTIFICATIONS					
2	RESILIENCE ECONOMIC SYSTEM (Ec)					
	Ec. 2.1	Reduce Construction Water Consumption	1,00 ----------- 0,00	0.05 ----------- 0,22	0,95 ------------ 0,07	By reducing the total costs of purchasing water Justified, see Note1*)
	Ec.2.2	Reduce Operational Energy Consumption For water transport	1,00 ----------- 0,00	0.05 ----------- 0,22	0,95 ------------ 0,07	By eliminating the costs for water transport Justified, see Note 1*)
	Ec.2.3	Reduce Construction Waste Balance Earthwork on site	1,00 ----------- 0,00	1,00 ----------- 0,00	1,00 ----------- 0,00	By using local materials
	Ec.2.4	Systems Preserve Water Resources	1,00 ----------- 0,00	0.05 ----------- 0,22	0,95 ------------ 0,07	By significant reduce consumption of water Justified, see Note1*)
	Total entropy Ec (bits)		0,00	0,66	0,21	
	JUSTIFICATIONS					

Note 1*)

Evaluation of the total economy savings, realized by using dry compaction technology

Calculations/ evaluations:

The average of the costs (million Euro) for the construction of 1 km new road, according to [5], website:

Austria: 12,87

Hungary: 11,21

Slovakia: 9,56

Cehia: 8,86

The average cost: 10,6

The cost of earthworks represents 20% from the total cost of the Tarhuna _Beni Walid road / 100 Km length the total cost:

Crt. No	The investigated resilience subsystem	Specific / envisaged project objectives/ or requirements	The probability for achievement of the specific project requirement and / its entropy value (bits) Ideal project: [X3]	Standard / classical project: (X2)	new proposed Project: (X1)	Observation/ comments/ justifications: project specifications or the desired/envisaged probability of achievement
	$0,20X\ 10,6 \times 10^6$ EUR / Km x 100 Km=21,200,000 EUR The savings obtained from eliminating the cost of purchasing, transport and spreading of the necessary water for classical Proctor wet compaction: Volume of earthworks: 100Kmx 1000m/Kim 0,60m x 2,1 t/m^3 =126000 tones Volume of water necessary for wet compaction: 126,000 t x 0,12=15.120 m^3 Cost of water purchasing, transport and spreading from a source locate at 100 km distance form the site: (15,120 m^3 / 5m^3/ water tank) x 75 EUR/transport = 232.243EUR; (this represents 0,011% from the total cost of earthworks or 2320 EUR/ Km)					
3	RESILIENCE ENVIRONMENT SUBSYSTEM (Env)					
		Env.1.1	Minimize Light Pollution	1,00 ------------- 0,00	1,00 ------------- 0,00	1,00 ------------- 0,00
		Env.1.3	Safety Minimize Noise & Vibration	1,00 ------------- 0,00	0,30 ------------- 0,52	0,60 ------------- 0,44
		Env.1.4	Minimize Construction Impacts	1,00 ------------- 0,00	1,00 ------------- 0,00	1,00 ------------- 0,00
	Total entropy Env. (Bits)			0.00	0,52	0,44
4.	RESILIENCE SUBSYSTEM OF ADAPTATION TO CLIMATE CHANGE (Acc)					
	Acc. 4.1	Protect Surface & Groundwater	1,00 ------------- 0,00	0,50 ------------- 0,50	1,00 ------------- 0,00	
	Acc. 4.2	Assess Climate Change Vulnerability	1,00 ------------- 0,00	0,50 ------------- 0,50	1,00 ------------- 0,00	By adapting to the desert conditions
	Acc. 4.3	Quality Enhance Functional Habitats	1,00 ------------- 0,00	0,00 ------------- 0,00	0,00 ------------- 0,00	No any enhance, due to the compaction technology?
	Total Entropy Acc		0.00	1,00	0,00	
5	REZILIENT SOCIAL & STRATEGIC SUBSYSTEM (SSD)					
	SSD 5.1	Reduce Net Embodied Carbon	1,00 ------------- 0,00	0,05 ------------- 0,22	0,95 ------------- 0,07	See Note 2*)

Crt. No	The investigated resilience subsystem	Specific / envisaged project objectives/ or requirements	The probability for achievement of the specific project requirement and / its entropy value (bits)			Observation/ comments/ justifications: project specifications or the desired/envisaged probability of achievement
			Ideal project: [X3]	Standard / classical project: (X2)	new proposed Project: (X1)	
	SSD 5.2	Reduce Greenhouse Gas Emissions	1,00 ------------- 0,00	0,05 ------------- 0,22	0,95 ------------- 0,07	See Note 2*)
	SSD 5.3	Reduce Air Pollutant Emissions	1,00 ------------- 0,00	0,05 ------------- 0,22	0.95 ------------- 0,07	See Note 2*)
	SSD 5.4	Avoid Unsuitable Development (by innovative compaction technology	1,00 ------------- 0,00	0,01 ------------- 0,07	0,99 ------------- 0,01	See Note 3*)
	SSD 5.5	Improve Infrastructure Integration	1,00 ------------- 0,00	1,00 ------------- 0,00	1,00 ------------- 0,00	
	Total entropy SSD		0,00	0,51	0,22	

JUSTIFICATION

Note 2*):

Conversion of the 56,264 metric tones of emission CO2e:

This is equivalent to greenhouse gas emissions, according to [6, 7], website:

10,998 gasoline-powered passenger vehicles driven for one year

Or:

126,696,339 miles driven by an average gasoline-powered passenger vehicle

Note 3*):

In the actual social and climate changing context, the dry compaction technology, by its significant and efficient contribution to the development of road infrastructures, fosters the use of local materials, saving and preservation of natural water resources, promotes the development of communication between people, the creation of new communities and of their social and economic progress;

Beside this, being an innovation, it contributes to the progress of the road technology in this field of earthworks.

Therefore it is very suitable to be use by NASA and other programs of space agencies in the future, not only on our planet but also on the envisaged transport infrastructures on the Moon and on the other planets (Mars, Venus, etc.)

Table 2. *Final Results of the Resilience Study.*

Crt no.	The resilience subsystem	The entropy values (bits) of each resilience subsystem		
		Ideal project	Standard reference project	New proposed project
1	T	0,00	1,29	1,29
2	Ec	0,00	0,66	0,21
3	Env	0,00	0,52	0,44

Crt no.	The resilience subsystem	The entropy values (bits) of each resilience subsystem		
		Ideal project	Standard reference project	New proposed project
4	Acc	0,00	1,00	0,00
5	SDD	0,00	0,51	0,22
	The total entropy value of resilience for the investigated projects	0,00	3,98	2,16

5. Conclusions

In relation with Table 2, where the resilience values of the subsystems of each of the resilience systems are considered, on may observe the following:

The new proposed project (X1), based on dry compaction technology has a resilient value significant less than that obtained for the reference/ classical project (X2), considered for comparison in this study.

Abbreviations

PIARC	Permanent International Association for Road Congresses
TC3/4	Technical Committee ¾
WG1	Working Group1
WG2	Working Group2
T	Technical Criterion
SE	Social Economic Criterion
E	Environmental Criterion
AC	Adaptation to Climate Change
AC	E Combination of AC & E Criteria
SS	Safety & Strategic Criterion
AASHTO	American Association for Highway and Transportation Officials

Author Contributions

Radu Andrei is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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